Paper Making Fibres—A Review

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SUMMARY

Since the time first recorded invention of true paper was made by Ts'ai Lun in A.D. 105, the paper industry has progressed by leaps and bounds. Today many types of fibres and fibre yielding materials are used in the manufacture of paper. These have included the bast fibres of flax and paper mulberry, the stalks of bamboo and other grasses, various leaf fibres, cottonseed hair, and the woody fibres of trees. The desire for more paper has prompted the search for additional sources of fiber, and conversely, the presence of large amounts of certain species has stimulated the technologists to determine whether these plants furnish a suitable raw material for papermaking. The need for papers with unique properties has led to research on the possibilities of glass fibers, rayon, nylon, orlon, Dacron and other synthetics. Asbestos fibres have been used for many years as have various animal fibers, especially wool.

The article illustrates some of the more important paper making fibres which have been in use through out the world.

1.0 HISTORY OF MAKING—IN PERSPECTIVE

The first recorded invention of true paper is in the Christian era; in about A.D. 105 Ts'ai Lun, in China, claimed the first truly felted sheet formed in a flat porous mould from macerated vegetable fibres. His raw materials were rags, waste hemp fishing nets and "shoes"., young shoots of bamboo and the inner bark of the mulberry were also used.

Some five hundred years later the art spread eastward to Japan and a hundred years later still, westward to Samarkand where, in 751, a mill was established by the Arabs using the skill of captive papermakers from China.

The Arabs carried the use of paper and the art of papermaking wherever they went, the latter reaching Baghdad in 793, Damascus and Egypt between the 10th and 12th centuries, Morocco in 1125 and Spain in 1156. From there the art spread northwards, to France in 1189, to England in 1484 and to Scotland in 1590. Its introduction to the New World was by two routes, from Spain to Mexico in 1580 and from Britain to North America in 1590.

It is of interest to note that similar and parallel developments took place in other parts of the world. The javanese and others used "bark cloth", whilst a Spanish chronicler records that the Aztecs and Mayas of Central America, using the inner bark of a variety of fig tree, one of the mulberry family, made a paper like that made in Spain, only whiter and thicker.

As the estimated date of the last of their calenders on stone is about the year A.D. 581, it may be assumed that, from that date, their records were made on such paper. The Spaniards found many thousands of books in their archives and libraries and, arguing that if these confirmed the teaching of the Bible they were needless and if they did otherwise they were pernicious, burned all they could lay hands on. This was in 1549. These bark cloth and other papers were made of macerated fibres but were in no case felted sheets.

Upto the end of the 18th century, papermaking remained essentially the same in both method and raw material. With the increase in demand, however, new methods had to be found, and in 1799, Nicholas Louis Robert invented in principle and patented in Paris what became known as the Fourdrinier machine. This invention was taken up later by M. Leger Didot, developed by Didot, Gamble and Donkin, patented under Gamble's name in 1803, and ultimately financed and successfully introduced by Henry and Sealy Fourdrinier in 1804; their first patent is dated 1806.

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1.1 PAPER MAKING FIBRES

Today many types of fibres and fibre yielding materials are used in the manufacture of paper. These have included the bast fibres of flax and paper mulberry, the stalks of bamboo and other grasses, various leaf fibers, cottonseed hair, and the woody fibres of trees. The desire for more paper has prompted the search for additional sources of fiber, and, conversely, the presence of large amounts of certain species has stimulated the technologists to determine whether these plants furnish a suitable raw material papermaking. The need for papers with unique properties has led to research on the possibilities of glass fibers, rayon, nylon, orlon, Dacron and other synthetics. Asbestos fibers have been used for many years as have various animal fibers, especially wool.

Slightly more than a century ago the paper industry began the use of wood as a fibrous raw material. Prior to the use of wood fiber the chief source of fiber had been cotton and linen rag, although some straw was used. Limited supplies of old rags had retarded the industry, and their shortage had often created serious problems for the paper makers. The availability of large amounts of a new raw material permitted the amount of pulp, paper and paperboard manufactured to expand greatly through the years. Improvements in printing and the spread of education in a world where wealth was becoming more widely distributed caused an ever increasing demand for paper.

The new Fordrinier machine, producing its continus web of paper from rags was mechnically able to meet this demand but rags and waste material in sufficient quantity were not available and alternatives had to be found. As far back as 1719 Reaumur had suggested extracting fibre from wood and throughout the 18th century chemists such as Schaffer, Charles Vilettee and Matthias Koops, made experiments with various woods, shrubs and grasses. Success, however, did not come until the middle of the 19th Century. Leblanc had obtained his patent for the manufacture of soda ash in 1791. A solution of soda ash (or caustic soda) dissolves the non cellulose part of the plant, leaving the cellulose in its natural fibrous form. The development of cheap caustic soda opened the way for the use of many new fibres the search for which had been going on for many years. In 1856 Routledge made paper from esparto fibres; in 18 9; Burgess and Logan successfully isolated the fibres from wood. In the mean time, working on different lines, Keller and Voelter produced, from wood, mechanical or ground wood pulp in 1856.

The type of fibres used for paper making in various countries is quite diverse, but on a world-wide scale, wood represents 85 to 90% of the paper making fibres consumed. It is interesting also to consider the changes that have occured in the species of wood used. A few decades ago spruce was the chief source in the world. Although spruce is still very important the use of the pines has increased rapidly. Recent figures show that the southern hard pines constitute about 50% of the pulpwood consumed in the United States.

Another point of interest is the fact that about 30% of our pulpwood is supplied by the hardwoods. or broad-leaved trees.

1.2 CLASSIFICATION OF FIBRES*

There are several possible ways to set up a classification of fibers; the following table is one that has been in use for several years.

I. **Vegetable fibers**

- A. Fruit fibers :
  - a. Seed hair-cotton
  - b. Pod-kapok
  - c. Husk coir
- B. Stem fibers :
  - a. Wood fibers-gymnosperm and angiosperm
  - b. Bast fibers
    1. Woody plants bast tissue in inner bark of gymnosperm and angiosperm trees (and shrubs).
    2. Herbaceous dicotyledons-flax, hemp, jute, sunn ramie.
  - c. Vascular bundles of monocotyledons-cereal straws, bagasse, bomboo, esparto, sabai, reeds.
- C. Leaf fibers abaca, sisal, phormium, caroa, pineapple.

II. **Animal Fibers**

- A. Wool

III. **Mineral Fibres**

- A. Asbestos
- B. Glass

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IV. MAN-MADE OR ARTIFICIAL FIBERS

A. Regenerated cellulose-rayon

B. Polyamide - nylon

C. Polyacrylic—orlon

D. Polyester—Dacron

While wood forms the major source of supply as fibrous raw materials for paper all over the world, there are many fibers other than wood which can also be used in the manufacture of paper.

1.2.1 NON WOODY FIBERS*

a) **Cotton**

Cotton fiber, which is the basis of most rag papers, is a single hairlime cell, flattened and twisted when fully ripe. The fibers form a covering on the cottonseed and are removed from the seed by ginning. The length varies from 12 to 33mm and the diameter ranges from 16 to 21 micron. The walls of nature cotton are thin.

Rags have been used for many years in the paper industry. At present, most of the better rags go into fine writing grades.

The supply of new rags comes largely from textile or garment factories, where cuttings and scraps are collected. Waste threads are now being used as well as the cuttings. The use of old rags for writing papers is decreasing. Large quantities of low grade rags are used for roofing papers.

Because of shortages the paper industry has been forced to use cotton linters and raw cotton in addition to rags. Cotton linters are quite short (less than 4 to 5mm). fibers which are removed from the seeds after ginning by means of cutters. They are used in the manufacture of chemical cellulose and stuffing materials and in papermaking.

b) **Kapok** :

Kapok fiber obtained from pods collected from the kapok tree, chiefly in Java, is used for stuffing pillows, life preservers, and mattresses and enters the paper industry to a limited extent as a waste material. The fibers are 10 to 30mm long and 20 to 45 micron wide, and they have very wide lumens and thin walls.

c) **Coir** :

Coir fiber is obtained from the husk of the coconut. It is used as a bristle in brushes and mats, in mattresses, yarns ropes and cordage. It enters the paper industry as a waste material. The ultimate fiber of coir has a length of 0.4 to 1.0mm, a width of 12 to 24 micron and a wall thickness about one third of the cell diameter.

d) **Bast Fibres** :

The bast fiber used in the paper industry is obtained from the outer part, or bast, of the stem of dicotyledonous plants. Often as in the case of linen, the fiber has been previously used in the textile industry or, perhaps, as rope or cordage. Some of these fibers have been used since the earliest days of paper making.

e) **Flax** :

Linen is obtained for textile purposes by retting the fiber strands from the outer parts of the stalks. The fiber, in the form of textile cuttings or scraps, is used in papermaking for fine writing papers, carbon papers and currency. The ultimate fiber has a length of 6 to 60mm (average 25mm) and a width of 12 to 26 micron. The fibers have thick walls with thickned places or nodes at intervals.

In addition to the bast fiber obtained as linen from plants grown for fiber, flax fiber is obtained from plants grown for the production of seeds for linseed oil. The stalks of seed plants have been harvested chopped, sieved and cooked. The pulp contain a mixture of bast fiber and shive (shorter cells from the woody core of the stem). It is commonly used for cigeratte paper and some other lightweight sheets.

f) **Hemp** :

Strands of hemp fiber are used in the cordage and extile industry and enter the paper industry as old cordage or rough textile waste. The fiber has a length of 5 to 55mm (average 22mm) and a width of 16 to 50 micron.

The walls are quite thick and like flax, have knots or thickenings at intervals. In Mills the hemp fiber has been used in certain speciality papers such as Bible and Cigaratte papers.

g) **Jute**

The supply of jute fiber is obtained from new burlap cuttings, washed sugar bagging and the wrapping material used on bales of cotton. Jute fiber is used with kraft in grades of paper where its hardness and durability give an added value. It finds extensive use in heavy duty shipping tags and in heavy pattern boards used in the garment industry. It is also used in colored bristols and detail drawing paper.

The fiber is 1.5 to 5 mm (average 2mm) long

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and 20 to 25 micron wide, with thick walls and a lumen of variable width. The fiber can be bleached only to a light yellow colour because of the lignin complex, which naturally limits its use.

h) **Sunn :**

Sunn fiber has a length of 4 to 12mm (average 8mm) and a width of 13 to 50 micron. It has been used in rope papers as a substitue or diluent.

i) **Ramie :**

Ramie is probably the longest of the plant fibers that have been used in the paper industry although its use has been very limited. The fiber is 60 to 250mm (average 120 mm) long and 10 to 80 micron wide.

j) **Paper Mulberry :**

The paper mulberry, or kozo, fiber has been used in papermaking since the earliest days of the art. The fiber is isolated from the inner bark of a small tree in eastern Asia and finds use in specialty sheets in Japan and other countries of the Orient The fiber is 6 to 20 mm (average 10 mm) long and 25 to 35 micron wide.

k) **Mitsumata and Gampi :**

These fibers are very similar in size and appearance, with a length of 2.4 to 3.6 mm and a width of 12 to 27 micron. They are used in certain Japanese speciality papers.

1.2.2 GRASS FIBERS

In this group of fibers are included those obtained from the vascular bundles of several monocotyledonous plants. These vascular bundles serve the plant for conduction and support. They contain fibers and several types of vessels. The vascular bundles are scattered in the cross section among the large, thin-walled isodiametric pith cells, or ground tissue.

a) **Cereal Straws :**

The straws of wheat, rice, oats, rye, and barley (especially wheat) have been pulped in various parts of the world since the early part of the nineteenth century. Two kinds of straw pulp are manufactured; the yellow pulp, used in the manufacture of paper tubes and cans, egg case fillers strawboards, and corrugating papers and straw cellulose invariably marketed in the bleached state and used in fine papers.

Typical fibers of these species are 0.7 to 3.1mm (average 1.5mm) long and 7 to 24 micron wide.hin Twalled fibers also present are of about the same length but have a width of 27 to 34 micron. Accompanying the fibers are numerous epidermal cells with toothed or serrated edges' alongwith smooth, thinwalled cells from the pithy portion of the stem and various vessel components from the vascular bundles. With the exception of certain vessel segments, which may reach a length of 1mm, these cells are considerably less than 0.5mm in length.

b) **Bagasse :**

Bagasse is the crushed stalks of sugarcane after sugar extraction. It has been used as a raw material for a wide variety of insulating and hardboard products for the building industries for several decades. Bagasse fiber, separated from the pith cells, can be used for the production of chemical pulp for book, writing, magazine and other papers requiring good formation, capacity and printability.

The fibers have pointed ends and are thin to thick walled with no characteristic markings in the cell wall except for the presence of occasional small pits. The length is 0.8 to 2.8mm (average 1.7mm) and the width is 10 to 34 micron. From the vascular bundles, in addition to the fibers, there are several vessel segments which range up to 1.3mm in length. There are also shorterparenchyma cells from the pith ond serrated epidermal cells in the pulp.

The structure of cornstalks is similar to that of sugarcane although the pith cells are reported to be shorter. Cornstalks are not currently used in the paper industry in the United States, but are reported to be used in Israel.

c) **Bamboo :**

The enormous quantity of bamboo in the world, and its very rapid growth, makes this grass a promising source of paper making material. More than 400,000 tons of bamboo pulp are produced in India and used in writing, printing, bank ledger and other classes of paper.

The typical fibers of bamboo are 1.5 to 4.4mm (average 2.4mm) long and 7 to 27 micron wide. Very wide, pitted, thin-walled fibers are 2.8 to 3.7mm long and 20 to 40 micron wide. Vessel segments, serrated epidermal cells, and avoid pith cells of various sizes and shapes are also present in the pulp.

d) **Esparto :**

Esparto fiber has been used in papermaking

in Great Britain for a century and more recently in France, Italy, and other countries in the Mediterranean region. The fiber seems especially suitable for the manufacture of high class book or printing and medium-class printing papers. Papers made from it are of a soft, impressionable nature, yielding clear impressions from type and blocks.

The fibers of esparto are 0.5 to 2.5mm (average 1.5mm) long and 4 to 11 micron wide with the lumen a fine line. Serrated epidermal cells are numerous but considerably smaller than those from straw. A distinguishing characteristic is the small tear shaped cell (trichome) from the hair on the leaves.

e) **Reeds :**

The common reeds which belong to the grass family and grow in marshes, on lake shores and along river banks have been examined. Gaint cane (*arund donax*) is pulped in Italy and Argentina. Another species, Danube reed (*Phragmites communis*), has been considered favourably and may be used in Rumania, Bulgara, Hungary and Russia.

1.2.3 LEAF FIBRES :

The textile and cordage industries have long used strands of fibers isolated from the leaves of certain plants. These strands are obtained by scraping away, by hand or machine methods, the various leaf cells surrounding the longitudinally oriented vascular bundles. Strands isolated for cordage or textile purposes may be several feet in length.

a) **Abaca :**

Of paramount interest is the cordage fiber known as abaca, manila fiber, or manila hemp (Musa textiles). In the paper industry this fiber is used chiefly by a group of mills known as makers of rope papers. These papers include flour and animal feed sacks, electrical insulation papers, sandpaper, shipping tags, gaskets and duplicating papers. Abaca is used in these sheets becausc of its fiber length and strength and ability to withstand shock. Most of the fiber used in these papers is from old rope, but limited amounts in the form of two are available from bordage manufacturers.

The bags and stensil sheets can be made nicely with manila fiber. A grade of virgin fiber is usually used for these.

The abaca fiber is 2 to 8 mm (average 4mm) long and 16 to 32 micron wide. The fiber ends show a gradual taper, the lumen is large and prominent, and fine cross markings on the walls are numerous.

b) **Sisal and Henequen :**

Sisal is a substitute rope fiber for making paper, said to be less strong and pliable than that from abaca. The fibers are 1.5 to 4.0mm long and 20 to 32 micron wide Henequen is a closely related species with demensions and properties similar to those of sisal.

c) **Caroa and Phormium :**

Other leaf fibers, especially caroa and phormium are used in papermaking. Caroa grows in Brazil and is used there principally for lightweight grades. The fiber has a length of 2 to 6mm and a diameter of 8 to 12 micron. Various related fibers such as pineapple, another fine diameter fiber are also used in specially grades.

Phormium fiber is native to New Zealand. It has been grown in Australia and used in mixture with kraft. The fiber is 5 to 15 mm long and 10 to 20 micron wide.

1.2.4 ANIMAL FIBERS :

Animal fibers in the from of silk, wool and specially hairs, and leather are encountered in certain aspects of the paper industry, such as saturating papers and longer grades of board. It is possible, since wool fiber is used in felt manufacture, that it might be found occassionally as a foreign fiber on paper surfaces.

1.2.5 MINERAL FIBERS :

a) **Asbestos fibers** have been used for many years to manufacture non combustible sheets. These fibers fracture readily, so it is impossible to make accurate length and width measurments.

b) **Glass fibers** are quit resistant to heat, chemical, and bacterial action. The fibers can be manufactured in controlled diameters down to about 0.2 micron. The major difficulty in the use of glass fibers for paper is the lack of fiber-to-fiber bonding. Recently technologists have succeeded in making paper out of glass fibers, and it is hoped that continued research will improve the results.

1.2.6 REGENERATED & SYNTHETIC FIBERS :

For several years the regenerated and synthetic fibers have been suggested for papermaking. As with glass fibers, the major difficulty hinges on the failure to develop strong fiber bonds when the fibers are formed and dried from water in the normal papermaking operation.

Techniques such as solvent bonding, synthetic polymer bonding and thermoplastic fiber bonding

have been suggested to improve this bonding because the synthetics have many desirable properties of in erest in speciality paper uses. The synthetic fibers are available in fairly uniform staple lengths as short as 3mm.

1.3 FIBRE CHARACTERISTICS*

The physical and chemical characterics of some important fibrous raw materials for paper can be compared from the following table :—

PHYSICAL & CHEMICAL CHARACTERISTICS OF SOME FIBROUS RAW MATERIALS

Raw Material	Material Texture	Fibre Dimensions			Ash %	Lignin %	Alpha Cellulose %	Pentosans %
		Avg. length mm	Avg. Diameter microns	L/D				
Rice Straw	Open	1.5	18.5	80	14-20	11 14	28 36	23-25
Wheat Straw	Open	1.5	18.0	83	3-5	15	30-40	25-30
Sabai grass	Open	2.08	9 0	231	6.0	22-0	54.50	18.76
Depithed sugar cane bagasse	Open	1.7	20.0	85	2.0	19-21	40-43	30 32
Jute sticks	Open	1.26	26.0	42	0.52	21.39	18.76	57.60
Bamboo	Dense	3-4	14.0	250	1.3	22-30	50.00	16-21
Coniferous wood	Dense	2.7-1.6	32-43	85	1.0	26-30	40 45	12.03
Board leaved wood (Hardwood)	Dense	0.7-1.6	20-40	80	1.0	18-25	38-49	17.80

From IPPTA Souvenir 1964.

Recent studies on co-relation of physical dimensions of fibre with properties of pulp reveal interesting facts; Not alone the fibre length but the following are inportant in determining quality of pulps : –

- Length of the fibre
- —Width of the fibre
- —Cell wall thickness
- – 'Lumen' width
- —Fibre quality or intrinsic fibre strength

Fibre wall thickness is most important to contribute to the freeness of pulp—The ratio of lumen diameter to fibre diameter has importance in contributing to sheet density, tensile and bursting strength. The favourable effects of increased L/D ratio is attributable to greater fibre flexibility and collapse. Tensile and bursting strength of pulp are also influenced by L/D ratio which contributes to increased fibre to fibre contacts in the pulps. The fibre therefore should not be neglected. On the basis of study of fibre length alone other properties like fibre width, lumen width, and intrinsic fibre quality have also to be studied for proper evaluation.

1.4 AGRICULTURAL FIBRES :

During the past ten years, as a result of tremendous increase in the worldwide consumption of pulp and paper combined with the desire of each area and each country, to have its own production facilities there has been a decided trend towards greater utilisation of agricultural fibres. Such fibres include bagasse, rice straw, wheat straw, reeds and fast growing species.

As a result of these demands for more paper, some paper making areas have already reached the limit for their wood fiber resources and as the population and demand for paper increase further, it will become more and more difficult to supply the world's paper from wood alone.

In addition to these growing demands for paper, there are many areas with no indigenous supply of wood suitable for paper making. These areas lacking wood are frequently the very areas where the demand for paper is expected to increase most rapidly. The pressure on paper supply due to population growth combined with the lack of suitable wood supplies in some areas have made it

*Compiled from "Raw Materials for more paper" IPPTA INTERNATIONAL SEMINAR, New Delhi April 11 & 12, 1964.

imperative that new supplies of paper making fibres be tapped. The agricultural fibres can form a sizable sum for supply to the paper industry. However the fact that an agricultural product or by product can be technically converted into pulp and paper is no indication that the operation is necessarily economically feasible. There are a number of qualifications which such a raw material must possess. Some important considerations are :—

—There must be ample supplies of raw material.

—It must be available to the pulp mill throughout the year.

—It must not deteriorate in storage over a reasonable period.

—It must have a good yield of quality fibres.

—It must be capable of being collected and stored in a small area and transportation cost should not be excessive.

—The cost of converting the material into paper must be reasonably low.

—It must make paper of sufficient quality to be competitive.

—It must not have a higher priority use.

Our agricultural wastes such as rice straw, wheat straw, bagasse are such that they satisfy all these requirements.

1.5 STRAW FOR PULP/PAPER—A STUDY :

Utilization of straw as a main raw material in paper making is no longer a new concept. Of late many paper mills in India have started making writing and printing paper from rice straw and wheat straw. However, the available straw is not fully utilised for various reasons.

India, with vast area of land under cultivation, has two main crops Rice and Wheat—with an annual production of 55/60 and 17/20 million tonnes respectively out of total agricultural production of 110/120 million tonnes. Though exact production figures of straw are not available several random estimates suggest a production of 1.5 tonnes of rice straw per tonne of rice and 2.0 tonnes of wheat straw per tonne of wheat.

Thus, about 70/80 million tonnes of rice straw and 35/40 million tonnes of wheat straw can be expected as agricutural wastes. The present utilisation indicates that some 50 to 60% of this straw is recovered for farm and non farm uses.

Since priorities are given for more important uses of straw a portion which is surplus to these needs is available and even 10% use of such free availability can be considered fair.

However, presently it appears that out of total production of straw in the country only about 1% is being used by paper industry. There were several difficulties as enumerated below in the use of straw, experienced by the paper within the recent past.

—Actual satistics regarding straw production and its free availability being not studied in detail for several regions of country.

—Transport difficulties in remote areas.

—Pulping process though well established has not been given technological importance/ improvements to be in line with the latest developments taking place in the paper industry the world over.

– Production of straw is seasonal and spread over vide areas; the material is bulky and therefore requires organised and special transport, baling and storage facilities.

—Supply prices fluctuate from year to year, depending upon crop and other major utility of this by-product.

—Collection of sufficient good quality raw material need most efficient organisation, equipments and long term contracts.

It is heartening to note that the Industry is trying to surmount these problems and today most of the paper plants being established in the country are essentially based on the utilisation of these agricultural wastes which will contribute a sizable quantity to the total production.

1.5.1. RAW MATERIAL UTILISATION PATTERN FOR THE PAPER INDUSTRY

Tha estimated production of paper and paper board and the utilisation of raw materials for the same are estimated as under:—

Year	Paper & Paper Board.	(Million tonnes) (Raw Materials)			
		Bamboo	Wood (Hardwood & Confrs).	Bagasse	Straw
1980-81	1.2	2.0	1.0	0.2	0.5
1985-86	2.0	2.5	1.5	0.4	1.0
1990-91	3.0	2.5	2.5	1.0	1.5

There are presently some 120 paper mills in the country which account for the total production of 1.1 million tons per annum, of paper board. Only 25 paper mills are categorised as large plants of 50 TPD capacity and above, utilising mainly the fibrous raw materials bamboo/hardwoods/conifers sabai grass and other forest resources. Yet these big mills account for some 70% of the total production of paper. The balance 30% production is accounted by the rest 80/90 paper mills - all of small capacities ranging from 3 tonnes per day to 50 tonnes per day. Perhaps in no other country such a structure is considered economically viable. Many of these small paper mills utilise such agricultural wastes as rice straw, wheat straw, bagasse, jute waste. hassian waste, rags and hosiery cuttings, white paper cuttings etc.

The existing forest resources are Practically committed to the existing large plants and with the Governmets concern for the denudation of forest resources, the preservation of ecology and soil erosion, there is no likelyhood of setting up forest based paper plants in the immediate future other than those already in the pipeline unless large scale planning is done for fast growing wood species. However very little improvement is being done in the forestry front. In view of this the short term planning for expansion of the paper industry must be met with by the utilisation of agricultural residues by setting up a number of mini paper plants in the different parts of the country.

It is in this context that use of straw has gained importance and is today the primary consideration as raw material of paper industry.

1.6 STRAW SUPPLIES FOR PULP & PAPER

It is of course misleading to consider the total quantity of straw produced when thinking of its utilisation for the pulp and paper industry. The actual amount of straw available is substantially less than the total amount produced primarily because only the straw growing areas within an economical radius 50/100 km can be considered for each particular location selected for setting up mini paper plant. Wheatstraw finds it use as fodder for cattle and for thatching of roofs of village houses. Rice straw is practically burnt as it is not put to any use.

1.7 STRAW PURCHASE, COLLECTION. STORAGE & PRESERVATION

Straw collection has to be done in an orgnised manner. The mill has to approach prospective farmers to negotiate the availability and price which essentially depends on the competitive and alternative uses. Wheat straw is used for fodder and for thatching and therefore the cost is likely to be high compared to rice straw. The yield of straw and the cropping pattern has to be closely investigated and local contractors are to be engaged for organising the collection/bale the same/load the bullock carts/ tractors for transport to site and unload at site for storage. It is ofcourse possible that the entire quantity of straw produced can be diverted by the farmers for use by the paper industry. This is because at present there is very little revenue for the straw consumed. Once the farmers are convinced that the straw is actually not a waste but can fetch them sizable revenue, they will themselves organise collection of the so called waste material and will find alternative sources of cattle feed fodder so that monetarily they will be benefited. It is therefore likely that the farmers will try to dictate the price for straw to the level where maximum revenue is obtained from which ever uses for the raw material. Even two paper plants in the vicinity can vie with one another for this. This setting of a monetary value for straw is a complex subject but any realistic evaluator of the material must take into account the uses.

1.7.2 STORAGE

While straw is available in large quantities, it is not possible to be readily available twelve months in a year. Being seasonal, depending upon the cropping pattern the cultivation can be for 4-6 months. For this reason the paper mills must plan operating on stored straw for atleast six months of the year.

A number of storage methods have been devised. Straw has been stored in bulk, baled and stacked or stored in bulk with water sprayed over the stack. Stacking is such as to allow free air. The usual stack is $66 \times 120 \times 30$ ft. The stack is normally protected from rain by laying sheet metal over it and pinning the sheets directly to the bales. It is then allowed to dry in storage to 10/15% moisture.

In recent years, a new method has been perfected for the storage of straw in bulk form, without baling. This method involves the use of a biological pretreatment of the straw and its subsequent bulk storage on large concrete Platform.

1.8 CELLULOSE PULPING FROM RICE STRAW

Commercial manufacture of paper from rice straw is not a recent development, it actually dates back to the early Chinese era of paper making. The first Chemical Straw Pulp was produced in 1800 by Mathias Koops. Williams Magaw obtained a patent

for pulping straw in 1828. Newspapers printed on straw paper were used in England during the 19th Century. Pulp and paper manufacture at that time was not favoured with the economic and technical benefits of modern techniques and equipments.

In the early days of manufacturing straw paper was widely used for wrapping meats and was not replaced as butcher paper until the early part of this century. It is still used in Europe for this purpose to some extent. The unbleached rice straw paper was the forerunner of the paper bags. The strongest types of papers from straw pulp were also achieved.

Various methods of pulping have been suggested from time to time for pulping rice straw, however, the actual method being dependent on the properties desired in the finally isolated cellulose pulp.

Industrial process for pulping rice straw employed in the world are;

1. Sulfate process
2. Sulfite process
3. Batch soda process
4. Batch monosulfite process
5. Lime process
6. Soda Ash Lime process
7. Morley Continuous process
8. Mechano-Chemical process
9. Pandia Process
10. Pomilio process
11. Huguenot process

Information available reveals that many countries in the world including Taiwan, Indonesia, Greece, Israel, Hungary, India, Rumania, Portugal, Spain, Combodia, Mexico etc. employ rice straw for the production of Cellulose pulp and all the plants are running successfully employing any of the above process and still many more plants are under construction. All the above processes are standard process and are more or less well established.

Rice straw contains less cellulose and lignin than wood, but more Hemicellulose and ash (high Silica content). Because of large amout of silica and low lignin content, straw cooking liquor must vary from that used in wood pulping. It has been reported by P. Lengyal that to remove 1% silica 1.33% NaOH is consumed. However, there are always some advantages and disadvantages in each process depending upon environments.

Specific surface of straw is 20 times that of spruce wood chips and the penetration of chemicals is so rapid that it is necessary to impregnate straw with cooking liquor.

Following points are worth considering for pulping of straw :—

—Clarification of rice straw before pulping aids in obtaining higher yields, stronger pulp and lower chemical consumption.

—Use of kneader before cooking aids in increasing specific surface of rice straw, rapid penetration of chemicals and shorter cooking time.

– Conventional pressure pulping techniques are not necessarily preferred for processing rice straw and easily bleaching pulp can be obtained by processing at atmospheric pressure.

—Various grades of paper from rice straw pulp can be obtained either alone or in suitable blend furnish with wood or rag pulp.

– With due modifications rice straw pulp can also be utilised for producing glassine or parchment paper.

In addition to straw there are avilable other fast growing raw materials such as sugar cane bagasse, hemp, jute, hassian, kenaf, mesta as well as hosiery cuttings.

Although some of these are expensive excellent improved methods have been developed for growing, harvesting and transporting. If specifically used for pulp & paper manufacture the process can be simplified and used in a proper with straw.

These raw materials have extremely long fibres and are ideal for blending with short fibred straw and bagasse. The existing mills utilising straw and bagasse are located in areas where pulpwood is either non-existant or in short supply. Therefore there are definite economic advantages in utilising straw pulp in contrast to wood pulp to the maximum extent for a particular grade of paper. The quality of such paper is as good as the paper from 100% woodpulp.

PROPERTIES OF STRAW*

Anatomical Elements'	Straw % Vol.
Epidermis	2
Bast & Wood vessels	4
Parenchyme cells	61
Fibres	30

*From IPPTA Souvenir 1964.

FIBRE CLASSIFICATION—STRAW

Long fibres	37.1%
Short fibres	42.7%
Fines fibres	20.2%

From a quality stand point straw pulp is particularly suitable for the bleached grades of paper, including fine writing and printing paper. In all these grades, bleached straw pulp can easily be used in proportions upto 90% of the total fibrous furnish, still maintaining a high quality of product.

1.9 CONCLUSION

The phenomenal success in the utilisation of bleached hardwood pulps, some of which are inferior to bleached straw pulp for most purposes, is an indication of the opportunities ahead for establishing bleached bagasse/straw pulp as an accepted world market commodity. From a use standpoint, the chemical and physical properties of bleached bagasse pulp and straw pulp lie somewhere between those of bleached softwood pulp and bleached hard wood pulp. However it has some desirable characteristics of its own which are not found in any wood pulp, and for this reason it might be used as a blending pulp to advantage in many grades of paper now being produced entirely from wood pulp.

In many grades of paper, bleached straw pulp might be used as an alternate for hardwood pulp, and in some grades even as an alternate for high quality bleached softwood pulp.

In view of the variety of papers in which it can be used, and taking into consideration the vast worldwide requirements for bleached pulp in the future, the potential for bleached bagasse pulp and straw pulp on the world market appears to be very great indeed.

PAPER MARKING FIBERS— A COMPARISION

PARTICULARS	PINE	SPRUCE	POLAR
Botanical name	Pinus	Picea	Populus
Fibre measurements	*Broad ribbon type fibers* Length : 2.6–3.7mm AV=3.0mm Width: 0.047–0.062mm AV= 0.05mm *Thinner type fibres* Length: 1.5–2.5mm AV= 2.0mm Width= 0.019–0.026mm AV = 0.022mm	*Broad ribbon type fibres* Length: 2.68–4.17mm AV = 3.5mm Width: 0.047–00.66mm AV= 0.05mm *Thinner type fibres* Length: 1.63–4.31mm AV= 3.1mm	*Fibres* Length: 0.53–2.68mm AV = 1.5mm Width: 0.01–0.039mm AV= 0.025mm *Pith Cells* Length: 0.37–1.30mm AV= 0.65mm
Ratio of length to width:	Broader ribbon type fibres = 60:1 Thinner ribbon type fibres — 91 : 1 (thickwalled)	Width: 0.016–0.023mm AV= 0.019mm Broad ribbon type fibres: 70:1 Thinner type fibres — 163:1 (Thickwalled)	Width: 0.047–0.19mm AV = 0.1mm 60:1

Extracted from paper making fibres by Tullis Russel Co Ltd., Scotland

PARTICULARS	BAMBOO	COTTON	FLAX
Botanical Name	Bambusa	Gossypium	Linum Usitatissimum
Fibre measurements :	*Fibres* Length: 0.40–4.2mm AV= 2.4mm Width: 0.005–0.047mm AV= 0.020mm *Small Pith Cells* Length: 0.054–0.70mm AV=0.28mm Width: 0.016–0.062mm AV=0.044mm *Large pith cells* *Length:* It is difficult to find complete cells. Most of them are fragmentary, giving no indication of their length. Some have been seen which were 3–4mm long.	*Thickwalled fibres* Width 0.01–0.031mm AV= 0.018mm Flatter ribbon line *fibres* Width: 0.022–0.033 AV= 0.028mm	Length: 3.2–13.1mm Width: Variation on same fibre from 0.005/0.008—0.016/0.023mm.
Ratio of length fo width:	120:1	(Cross & Beaven) 1250:1	(Cross & Beaven) 1200:1

PARTICULARS	EUCALYPTUS	ESPARTO	STRAW (Wheat)
Fibre measurements :	Broader ribbon type *fibres* Length:0.39–0.92mm AV=0.6mm Width:0.019–0.039mm AV= 0.021mm Thicker walled *narrower fibres* Length 0.51–1.47mm AV=1.0mm Width:0.01–0.026mm AV=0.018mm Small perforated *pith cells* Length:0.039–0.19mm AV=0.1mm Width:0.016–0.039mm AV= 0.025mm Large perforated *pith cells* Length: 0.34–0.68mm AV= 0.5mm Width: 0.19–0.39mm AV= 0.28mm	*Fibres* Length:0.093–3.55mm AV = 1.25mm Width 0.004–0.016mm AV 0.01mm *Epidermal Cells* Length:0.023—0.116mm AV= 0.06mm Width:0.01–0.023 AV=0.01mm *Tooth Cells* Length 0.031–0.062mm AV=0.04mm Width 0.012–0.023mm (at base) AV=0.015mm	Broad woody & normal straw *fibres* Length 0.68–2.63mm AV=1.5mm Width 0.012–0.29mm AV=0.018mm *Small sparto type fibres* Length 0.28–0.81mm AV=0.6mm Width:0.005–0.01mm AV=0.007mm *Perforated pith cells* Length:0.34–0.98mm AV=0.55mm Width 0.031–0.047mm AV=0.035mm *Cushion type cells* Length 0.078–0.34mm AV=0.2mm Width 0.031–0.093mm AV=0.06mm *Epidermal cells* Length:0.023–0.39mm AV=0.12mm Width:0.016–0.047mm AV=0.025mm *Ring Cells* External diameter:0.016–0.039mm AV=0.025mm Thickness:0.003–0.005mm AV=0.004mm
Ratio of length to width:	Broader ribbon type fibres: 29:1 Narrower fibres: 56:1	125:1	Broad woody and normal straw fibres : 83:1
Botanical Name :	EUCALYPTUS	STIPA TENACISSIMA	TRITICUM SATIVUM

PARTICULARS	MANILA	SISAL	JUTE
Botanical Name	Musa Textilis	Agave Rigida	Corchorus
Fibre measurements	*Larger type fibres* Length:5.18–8.32mm AV= 6.2mm Width:0.016–0.023mm AV= 0.018 mm	*Common fibres* Length:1.60–4.29mm AV=2.7mm Width:0.008–0.031mm AV=0.019mm	Length:1.14–3.78mm AT=2.5mm Width:0.008–0.028mm AV=2.5mm
	Smaller type fibres Length: 1.10–2.87mm AV=1.8mm Width 0.008–0.016mm AV=0.011mm	Broad fibres with *lattice pattern* Length: 1.01–1.44mm AV=1.3mm Width:0.031–0.039mm AV=0.037mm	
	Rectangular cells Length:0.062 0.124mm AV=0.09mm Width:0.016–0.031mm AV=0.025mm	*Cushion type cells* Length:0.047–0.31mm AV=0.15mm Width:0.031–0.047mm AV=0.043mm *Rectangular cells* Length:0.062–0.16mm AV=0.12mm Width:0.016–0.023mm AV=0.018mm	
Ratio of length to width :	Larger type fibres : 254:1	Common fibres : 142:1	156:1

Extracted from paper making fibres by Tullis Russel Co. Ltd., Scotland